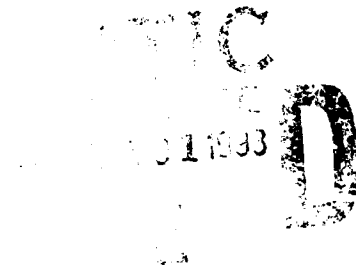AD-A271 704

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

TELECOMMUNICATIONS SERVICES FOR
MULTIMEDIA DATA EXCHANGE SUPPORT

by

Paul C. Gibbons

June 1993

Principal Advisor: Myung W. Suh

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Multimedia holds the promise of increased knowledge, creativity and productivity for virtually any application that can be imagined. The ability to present information in both an informative and entertaining way can lead to an enhanced quality of life for an increasingly larger segment of the world's population. However, information generated in a multimedia format presents special challenges for communication networks. This thesis is an attempt to understand the impact of multimedia computing as it relates to the transmission requirements to support large volume data exchange in a distributed computing environment. With a good understanding of these requirements one will be better equipped to evaluate the various physical transmission media and communication services available to meet the high transmission demands imposed by multimedia data exchange.

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TELECOMMUNICATIONS SERVICES FOR MULTIMEDIA DATA EXCHANGE SUPPORT

by

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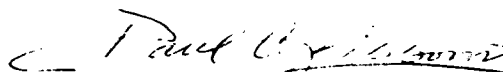Submitted in partial fulfillment

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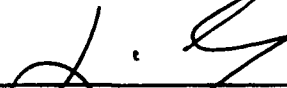from the

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ABSTRACT

Multimedia holds the promise of increased knowledge, creativity and productivity for virtually any application that can be imagined. The ability to present information in both an informative and entertaining way can lead to an enhanced quality of life for an increasingly larger segment of the world's population. However, information generated in a multimedia format presents special challenges for communications networks. This thesis is an attempt to understand the impact of multimedia computing as it relates to the transmission requirements to support large volume data exchange in a distributed computing environment. With a good understanding of these requirements one will be better equipped to evaluate the various physical transmission media and communication services available to meet the high transmission bandwidth demands imposed by multimedia data exchange.

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To my wife Deborah, whose love and support throughout every aspect of my military career, and our life together has assisted me in every accomplishment.

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I. INTRODUCTION

A. OBJECTIVES

The purpose of this thesis is to provide the reader with a comprehensive discussion of multimedia computing as it relates to the transmission requirements to support large volume data exchange in a distributed computing environment. With a good understanding of these requirements one will be better equipped to evaluate the various physical transmission media and communication services available to meet the high transmission bandwidth demands imposed by multimedia data exchange.

B. BACKGROUND

The field of computing continues to evolve primarily due to technological advances in equipment, operating systems and application programs. As the advances in microminiature circuitry permits increased central processing unit (CPU) speeds, the ability to manipulate larger volumes of data has opened up new computing horizons.

An attendant benefit derived from advances in manufacturing of computer circuitry is the decreasing costs associated with producing microcomputer components and end-user systems. This has allowed a wider variety of consumers to acquire computing devices, thus expanding the user base. This

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increase in the number and types of users has seen a commensurate increase in the need for easier to use and more productive applications.

What is being experienced over the past two decades is that computer systems are becoming more "user friendly." Today's trend finds the computer better able to communicate with the user in terms more amenable to the human. These breakthroughs are a direct result of the increased processing speeds of the computer, especially the "personal computer", which is how the vast majority of users connect to the world of comput. ^ It is these faster, more "powerful" computers that have provided the advances in operating systems and application software which enable computers to interface with people in a more familiar way.

A logical outgrowth of the increased capability to more effectively and efficiently interact with a computer has been the development of multimedia technology. Gone are the days when a person had to work in isolation with a computer to produce or obtain information which was intelligible only via a cathode ray tube or printer. Today a person is able to "visualize" information in forms other than printed text or graphics.

The communication of information in multiple media formats has advanced the ability to effectively dispense knowledge and entertainment. This technology holds the potential to increase knowledge acquisition and productivity in leaps and bounds.

It is widely known that a person's ability to learn is affected by the manner in which they receive the information. Some learn well through reading, while others benefit more from seeing or hearing tne intended message. Multimedia computing provides us with the ability to communicate our intended message using a combination of sound and sight. Especially impressive are the advances which permit visual images, other than text, to be represented in a variety of forms.

Advances in computer capabilities have expanded beyond benefiting stand alone computers. Innumerable machines are linked today in a cooperative environment, making each of them more efficient and effective. Efficiency is improved through new hardware and software capabilities which enable faster information processing. Effectiveness is enhanced because machines in a networked environment have access to larger information bases.

One of the industries which has benefitted most from the increased capability to incorporate computer technology into equipment is the communications industry. Just as people have reaped the benefits of more capable computing systems, so have they felt the power and freedom attainable through more potent communications infrastructures.

The speed, capacity, and dependability of various communications systems have been developed through the integration of many technologies, of which computerization is

just one. However, there is no doubt that just as computer science has bestowed increased capabilities upon communication companies, these very improvements have provided the computer science field with increased opportunities to expand the ways in which computers can be made more powerful and useful.

With the ability to establish quality communication connections, it is now possible, perhaps even required, that computers should be connected into more powerful networks. The ability to establish such networks opens up new opportunities for improving the support computers can provide in numerous area of work, education, and leisure.

C. ORGANIZATION OF THE THESIS

This thesis begins by taking a look at what "multimedia" is: its capabilities, limitations and applications. What is it about multimedia that poses a problem in creating an accessible and effective communication environment? Distributed computing networks will be explored to determine if local area networks can support the exchange of multimedia information. What are the "long-haul" communications systems in operation today that are capable of providing an adequate "data highway" for the transfer of multimedia information. Finally, an opinion will be offered as to which technologies provide the best promise for supporting the current and future multimedia information transfer requirements.

II. A DESCRIPTION OF MULTIMEDIA

Multimedia communications is a relatively new form of computer based communications that is quickly becoming the center of attention in the computer software and hardware development arena. Growth potential in the multimedia field is predicted to reach $9 billion by 1997. Estimates indicate that by this time 34 percent of all personal computers in use will have a multimedia peripheral of some form attached, and that 17 percent of the software loaded onto personal computers will be multimedia applications (PCUS92 p. 20). The use of multimedia systems can be viewed from two perspectives: stand alone systems and networked, or distributed, systems. While the goal of each system is basically the same, it is how these systems will be used that sets them apart.

A. WHAT IS MULTIMEDIA?

Multimedia is the combination of different media elements such as text, audio, video, graphics, animation and still images for the display on, and control from, a computer. (See Figure 1.)
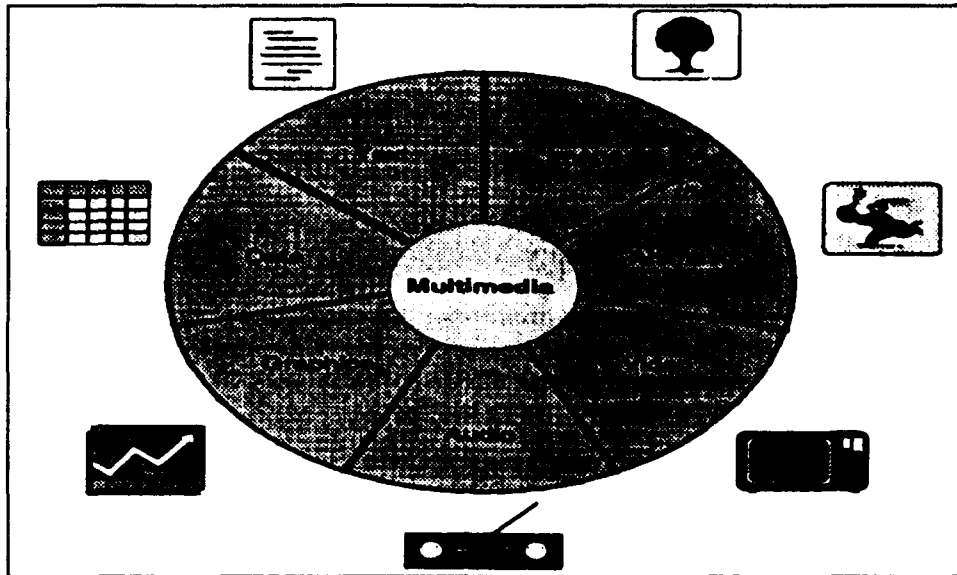
Figure 1. Media Elements of Multimedia (IBMC92)

Multimedia presentations can be made combining any two or more of these forms into a single presentation. The integration of numerous forms of information in this manner is intended to enhance the effectiveness of delivering information, whether its purpose is for entertainment or education.

B. EXAMPLES OF MULTIMEDIA USES

The potential uses for multimedia communications are virtually limitless. However, a description of some of the current applications will provide a good background for understanding why multimedia is seen as such an important development in the field of computer communications.

1. Videoconferencing

Videoconferencing at a basic level would entail the synchronized transmission of audio and video signals to permit the simulation of a "face-to-face" discussion. This simulation is considered to take place in the form of at least two parties seeing and hearing each other in realtime. It may also take the form of a one way broadcast or transmission, or it may have several locations in "conference" together. Videoconference sessions can also be stored for delayed play or for referencing in a replay fashion.

Videoconferencing can also developed into a much more complicated format than simply seeing and hearing another person. With the addition of other forms of information such as text, video, or animation simultaneously displayed on the same screen, it can take on quite a different appearance, serving a much broader purpose.

Initially envisioned as primarily applying to the business sector, it is not difficult to see how video conferencing could rapidly expand into the private sector too.

A significant potential in this area is the ability of deaf people to communicate through the use of sign language and to read lips, or to have people of different languages communicate effectively and efficiently through the use of voice recognition programs that performs realtime translations.

2. Education and Training

Classrooms of today, and those in the future, will see increased use of multimedia-based education. With the ability to combine information in various forms, multimedia is capturing the imagination of today's youth. Having grown up with television, easy access to video movies and "Nintendo" type video games, and the introduction of personal computers into the regular school curriculum in the mid 1980s, children and students are accustomed to viewing a video screen of some form from early childhood.

Because of this, a transition to computer-based educational systems displayed on a monitor seems only natural. The receipt and control of information on the screen through the use of a joystick, mouse or keyboard has become almost as natural to them as the use of books, blackboards and pencils had been to their parents and elders.

An extension of this is that the corporation of the future must begin to acquire the ability to train their new employees through the same methods. If multimedia-based education becomes prevalent in the school systems, then the corporate training programs will have to follow suit.

3. Merchandise Shopping

Shopping for merchandise from the comfort of your home is already a reality through the use of the telephone. Cable

television channels exist today to cater to those who prefer this method of shopping.

Yet, the convenience that this arrangement provides today will easily be eclipsed by the ability to "dial up" on-line catalogs of goods that include advertisements and descriptions in any form supported by multimedia technology.

4. Medical Support

The medical field can achieve great advantage from the use of multimedia communications. The ability of a patient to confer with, or receive a diagnosis to an ailment from, a specialist at a distant location is possible through videoconferencing.

Doctor-to-doctor consultations at remote sites to discuss surgical proceedings during the event or after the fact can be supported through the use of video, audio, animation and image technology provided in multimedia.

5. Cooperative Computing

Cooperative computing is an environment where two or more people, using separate computer terminals, work together simultaneously sharing the same information. Obviously such an arrangement would require the computers to be networked in some form.

Possible scenarios for cooperative computing could include an architect and his client reviewing blueprints to determine if the plan meets the client's desires.

Rearrangement of a room layout or changing its dimensions could be done on the screen by either party while in full view of the other party.

Drafting a document, proposal, or presentation by business partners could be done in real time. Editing changes could be seen immediately and a consensus arrived at in real time. The obvious time and effort savings could lead to a significant competitive advantage.

These are brief descriptions of just some of the many possible scenarios in which multimedia computing and communications can benefit people. The applications of multimedia computing appear to be limited only by the imagination of the people who would design or use the services available through multimedia technology.

C. HARDWARE REQUIREMENTS FOR MULTIMEDIA

The hardware requirements to support multimedia computing and communications vary depending on whether you are considering a stand alone system or a distributed system.

1. Stand Alone Systems

The requirements for a stand alone system are relatively few and simple. A nominal unit would consist of a 80386 or 80486 microprocessor based personal computer with monitor, keyboard, hard disk drive and floppy disk drive. Additional input devices such as a mouse, joystick, or touch

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screen monitor would ease data entry. Operating system software and application software is also required.

Peripherals required to view multimedia presentations would include a sound card and speakers, a video card to support enhanced pictures, and a compact disk-read only memory (CD-ROM) or videodisc (laserdisc) player to retrieve stored audio and video recordings.

Advanced presentations, in particular a presentation one would choose to create, would require a microphone to record audio, and perhaps a video camera and recorder to record audio and video images for playback. As the type and length of multimedia presentations increase, the need for larger and faster storage devices becomes more imperative.

2. Distributed Systems

In addition to the equipment required for stand alone systems, a distributed system will require the means to connect to a communications system of some form. Telephone modulator-demodulators (Modems) and network interface cards are examples. Exact requirements will depend upon the type of system to which it is connected, such as the telephone system or radio wave based system.

Many computers are now connected to a local area network (LAN), which is in turn connected to other LANs through a wide area network (WAN) or a metropolitan area network (MAN).

In a distributed system the need for large dedicated storage devices becomes less important. The very nature of a distributed system defines that data storage devices of varying sizes and for different media can be maintained at remote sites from the system being used, and accessed when required.

The use of multimedia in a distributed environment will require that special equipment be used to control the access to, and supply of data, to the various workstations. Servers located at different points throughout a distributed system will provide the access to and control of the data and multimedia information requested.

D. SOFTWARE REQUIREMENTS

Software requirements for multimedia computing are not significantly different from today's computing specifications. Multimedia capable computers still require operating system software that controls the computer and makes it capable of recognizing and obeying commands typed by the user.

The predominant operating systems in use today are IBM's OS/2, Microsoft's MS-DOS and Microsoft's Windows. OS/2 and MS-DOS with Windows provide the user with a graphical user interface (GUI) that makes controlling the computer easier by providing the means to interact with the computer through icons rather than by typing DOS commands. (See Figure 2.)
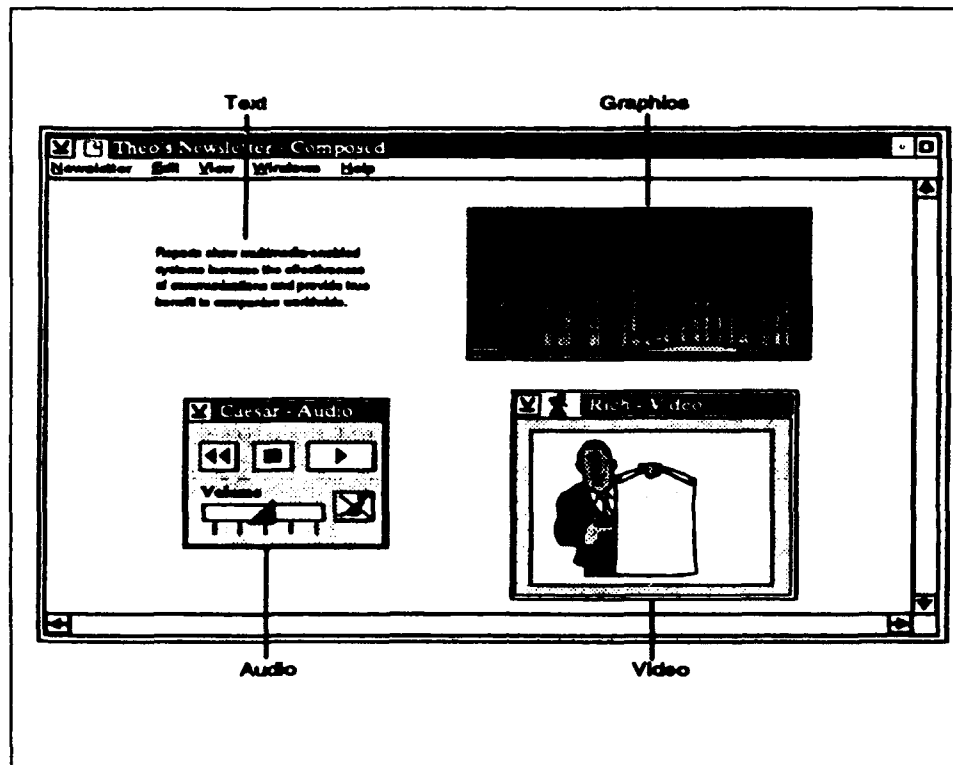
Figure 2. Graphical User Interface (IBMC92)

Application programs are still required to perform useful work not related to the computer itself. Common application programs include word processors, spreadsheets, or accounting systems. Multimedia application programs are similar to current application programs except that they permit the user to access a greater number of peripheral devices which store information in the form of audio, video, animation or graphics.

By combining two or more information formats, one is able to enhance the understanding of the presented information. For

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example, a voice annotation of a spreadsheet would help to highlight any nuances not readily apparent by viewing the numbers alone.

Multimedia specific software will most likely be stored in mass storage devices such as CD-ROM, laser disk, or video tape.

Perhaps the greatest change, and challenge, in software is the requirement to develop software that is capable of compressing and decompressing the data in the large file sizes associated with multimedia. Compression techniques are required to save valuable storage space and to enable faster transmission times over networks.

While compression software holds the ability to reduce the size of a file -- thereby increasing the speed at which it can be transmitted across a network -- it does have its limits. The various techniques for data compression will not be covered in this thesis but, it is important to know that such tools exist. In many systems, compression software is implemented in hardware-based logic (i.e., firmware) for better performance. For further information on data compression, see (WRIG90 p. 34-40).

E.   THE INFORMATION EXCHANGE CHALLENGE

Because multimedia incorporates information in various forms it poses a problem in the exchange of that information over telecommunication systems. This is a result of large file

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size, and high transfer speed requirements to support audio and video formats.

1. **File size**

Most computer users are accustomed to viewing and working with information in a text-only format. Computers were designed to represent letters, numbers, punctuation marks and a few other special and control characters using a binary code which is easily translated and stored in an electrical device. This code is known as the American Standard Code for Information Interchange (ASCII).

A text file, such as a letter, can be readily represented by ASCII characters and stored in a relatively small amount of space. This thesis for example could be stored in a file of 600,000 bytes of information.

However, a high-quality, 30-second voice message could easily consume 150,000 or more bytes of storage space (VANN92 p. 113). Voice annotations of various forms of information will be a normal occurrence in multimedia sessions, not to mention the sound or music accompaniments of business or educational presentations. Surely, such added features will be measured in tens of minutes rather than seconds, which will increase the requirement for storage space.

High-resolution graphics or still images present a similar problem. As the number of colors used increases or the finer the resolution becomes, more bytes are required to

represent them. A display with a resolution of 1,280 by 1,024 pixels requires 1,310,720 pixels. Showing 256 simultaneous colors at this resolution requires one byte per pixel to hold the color information for one full screen image (VANN92 p. 113). A 14 by 17-inch medical x-ray film image requires 120 megabytes (WRIG90 p. 35).

As full-motion video capabilities are added to a multimedia presentation, the storage requirements skyrocket. Digitized video can require up to 30 megabytes per second (DAVI91 p. 75). Ten minutes of uncompressed audio and video from the evening newscast require 27 gigabytes (DECP92 p. 36).

2. Transfer Speeds

The larger file sizes that are synonymous with multimedia computing levy a heavy burden on the ability of systems to get the data to its destination in a timely manner. When considering transfer speeds, it is important to consider the purpose the data transmission is to serve.

The International Consultative Committee for Telephone and Telegraph (CCITT) classifies transmission services as being either interactive or distributed. Distributed service is a one-way transmission with no backward channel. Examples include present-day, broadcast television and radio.

Interactive service represents transmission in both directions. This is broken down further as to being either conversational or messaging service. A conversational mode

implies that the sender and receiver of the information are simultaneously present. Messaging entails the sending of information to a database for subsequent retrieval (WRIG90 p.34).

The understanding of these differences is important because they imply the presence or absence of numans in the transmission scenario. When people are absent, as is the case in messaging, transfer rates become less important. The conversational mode on the other hand indicates that people are directly influenced by the speed in which they can send and receive their data.

As described, multimedia information will be of a significantly larger volume than what has been considered normal in the past. The sequencing and synchronization of certain aspects of multimedia (audio and video) information again place a heavy burden on a system's ability to deliver the data on time. Highly efficient transmission networks will be those that are capable of passing compressed data at a rate of 64 to 128k-bps. Full motion video (at 30 frames per second), if highly compressed, can be efficiently transmitted at speeds of 32 to 128k-bps.

What will be discussed in the following chapters are the current and future network and telecommunication services available to efficiently and effectively transmit the larger data files required in a multimedia environment.

III. LOCAL AREA NETWORKS

With an understanding of multimedia computing as described in the preceding chapter, one must find a method to efficiently and effectively store and transmit files of vastly larger sizes associated with multimedia.

This can be accomplished by using a distributed processing environment, and in particular in the use of a local area network (LAN). The broadest possible definition of a LAN is a communication network used by a single organization over a limited distance which permits users to share information and resources (SCHA92 p. 14). LANs have been in use for a number of years in the business and education sector, and it is estimated that by 1996, 89 percent of businesses will be using LANs (EDGE92 p. 11).

An obvious advantage of a LAN is its ability to share high volume storage peripherals. These storage devices can take many forms, such as: hard disk drives, magnetic tape drives, and compact or laser disks. Storage capacities of these devices range from hundreds of megabytes to tens of gigabytes.

Another advantage of a LAN is its ability to connect a number of users to the same network so that they can share information, as well as hardware resources. Yet, it is this very physical separation of users and devices that presents an

obstacle to the transmission of information, especially multimedia information.

The fashion in which a LAN is constructed, or its topology, the network standard or protocol it is run under, and the physical medium it uses to interconnect the various nodes and peripherals all play a part in determining the LANs ability to support multimedia computing.

A view of the topologies a LAN can assume and a description of the protocols a LAN can use will briefly be presented. Because the emphasis of this thesis is on the physical transmission mediums available to support multimedia computing, a more in-depth look at the available mediums will be provided next. Particular emphasis will be placed on what mediums are currently most in use.

A. TOPOLOGIES

LANs can be configured in a variety of forms, or topologies. Each topology has its strengths and weaknesses, and has been designed to meet a different set of customers' needs (SCHA92 p. 54).

1. Bus (Daisy Chain)

A bus topology can be thought of as a data "highway" that connects several LAN workstations. In this configuration a message is sent along the entire length of the bus with each station checking the message destination address to see if it matches its own address. (See Figure 3.)
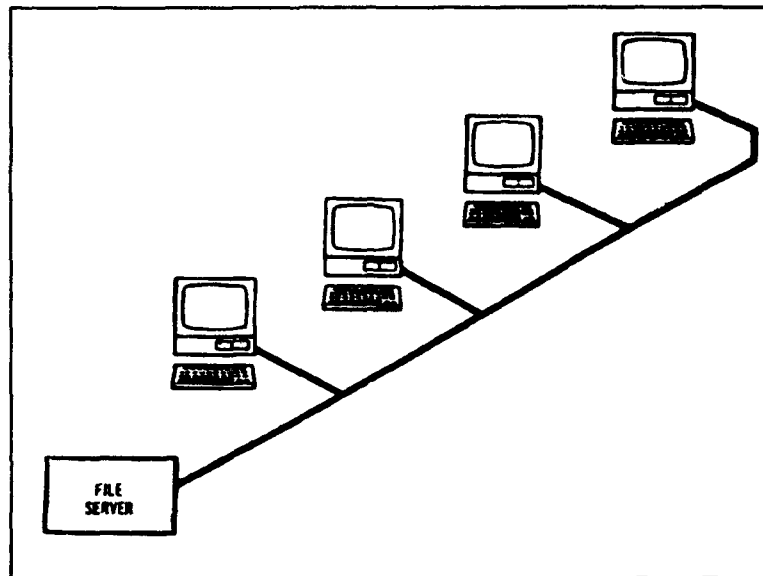
Figure 3. Bus Topology (SCHA92)

Advantages of the bus topology are that it requires the least amount of cable, and the failure of any single workstation will not cripple the rest of the network. Disadvantages include the requirement for a minimum distance between taps for workstations to avoid signal interference, and the lack of security as a result of all messages flowing to every workstation.

2. Star

The star topology uses an approach to sending messages similar to the telephone network. All messages sent from one workstation to another workstation or peripheral device must go through a central switching station. (See Figure 4.)

Advantages of the star topology are that it is easy to add new workstations, and historically busy nodes can be
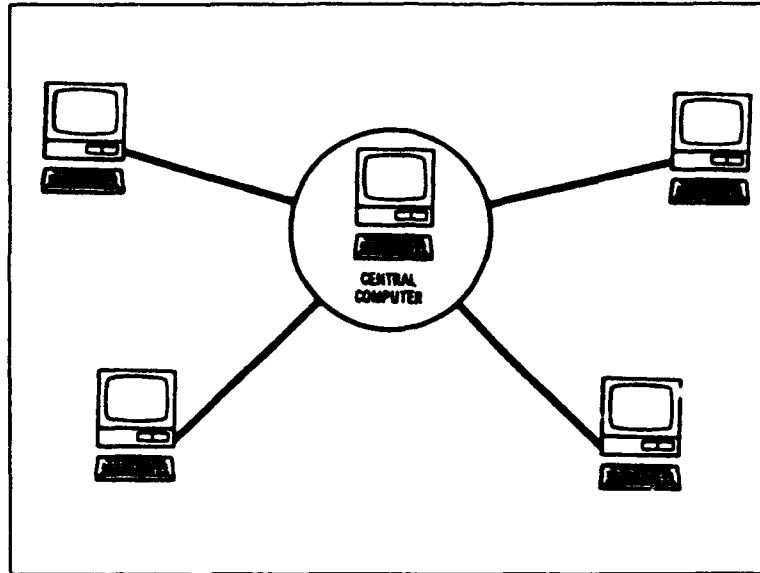
Figure 4. Star Topology (SCHA92)

assigned a higher status than other nodes by the system administrator. The critical weakness of this arrangement is that if the central computer fails, the entire LAN is put out of business.

3. Ring

The ring topology consists of several workstations joined together in the form of a circle. (See Figure 5.) One workstation assumes the role of monitoring all network functions. Messages are passed from node to node in one direction only. (Although some ring networks are configured with dual cabling to permit bidirectional transmission, a message can only travel in one direction at a time.)

Advantages of the ring topology include the ability to verify that a message has been received by the intended workstation. Should the network monitor workstation fail, it

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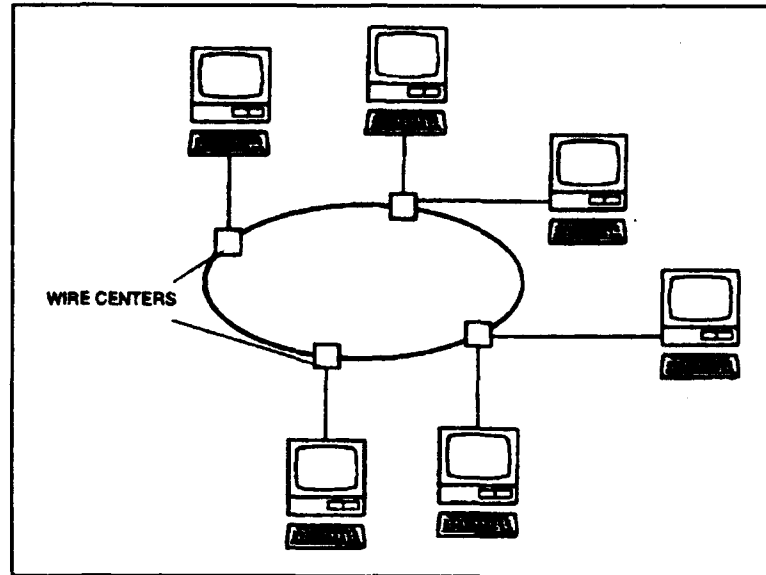
Figure 5.   A Ring Topology (SCHA92)

can be bypassed and another workstation will assume the monitoring functions. (This can be arranged in advance by the use of bypass software.) Disadvantages include the need to shut down the LAN when adding or deleting nodes unless special connectors, called *wire centers*, are used. Another major concern is ensuring that all nodes have equal access to the network. This is accomplished through the use of a *token*, which will be explained later in this chapter.

B.   NETWORK STANDARDS

The Institute of Electrical and Electronics Engineers (IEEE) committee 802 has established standard network access methods which apply to the main topologies listed above. These different, and sometimes contradictory standards, were established to bring some order to the often chaotic realm of

LANs. The benefit of establishing standards is that the manufacturers who comply with these standards will produce hardware that can work in the same system (SCHA92 p. 54).

1. IEEE 802.3 - CSMA/CD Bus

The CSMA/CD bus standard of IEEE 802.3 has its roots in Ethernet. Ethernet was developed by the Xerox Corporation, and is normally associated with the use of 50-ohm coaxial baseband cable with a 0.4 inch diameter, and is capable of sending data at 10 mega-bits per second (M-bps) (DOWN92 p. 124).

a. CSMA/CD Protocol

Carrier Sense Multiple Access with Collision Detection (CSMA/CD) is a medium access control protocol used with Ethernet in order to prevent the collision of data travelling on the cable at the same time. Each node listens to see if another node is transmitting. If so, it waits its turn to transmit. If two nodes inadvertently transmit at the same time, the collision is detected and they retransmit one at a time (DOWN92 p. 124). CSMA/CD is used with the following physical specifications.

b. 10Base5

This is the original Ethernet specification. It describes a bus network with *thick* baseband coaxial cabling with a 0.4 inch diameter that can transmit data at 10M-bps over a maximum distance of 500 meters. Stations attach to the

cable by means of a tap, with the distance between any two taps being multiples of 2.5 meters to reduce phase reflections. A maximum of 100 taps are allowed (SCHA92 p. 57).

c. 10Base2

This standard describes a bus network that can transmit data at 10M-bps over *thin* baseband coaxial cabling with a 0.25 inch diameter, for a maximum distance of 200 meters. This thinner cable is easier to bend, and thus install directly to the workstation (SCHA92 p. 57).

d. 1Base5

This standard describes a *clustered star* topology in which stars are linked to each other. Data can be transmitted at 1M-bps for a distance of 250 meters using two pairs of 24-gauge, twisted-pair unshielded wire (SCHA92 p. 57).

e. 10BaseT

This standard combines the best features of a star and a bus network. Logically configured as a bus with data transmitted over the entire network, it is physically configured as a distributed star. Using twisted-pair wire, this network can transmit data at 10M-bps for a maximum distance of 100 meters (SCHA92 p. 57).

f. 10Broad36

This standard uses 75-ohm coaxial cable and a broadband signaling technique to provide a maximum data rate of 10M-bps over a maximum segment length of 3,600 meters.

2. IEEE 802.4 - Token Bus

This standard was designed to meet the needs of a bus network when it is absolutely necessary that there be no data collisions. It was designed to eliminate the contention problems encountered in the CSMA/CD protocol by circulating a special data packet, or "token."

Only one workstation at a time can possess the token. Since only the node "owning" the token can transmit information, this effectively eliminates the possibility of data collisions (SCHA92 p. 58).

3. IEEE 802.5 - Token Ring

This standard was developed to cover LANs with both a physical and logical ring topology that use a token to control the media access. As the token, or a token with an attached message, is received by a node, the signal is repeated and sent farther along the network.

The major advantage of a token-ring over a token bus network is that it can cover a greater distance without the loss of signal because each node on the ring repeats (regenerates) the signal.

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Care must be taken to plan for the potential outage of a node along the ring and to bypass the disabled node. One way to handle this problem is to use hardware, such as wire centers.

4. ANSI X3T9.5 - Fiber Distributed Data Interface

While optical fiber cable is being used rather extensively in long haul communications systems such as telephone networks, only recently have vendors and users focused on using fiber optics to support LANs. The current interest is in fiber distributed data interface (FDDI) to connect nodes in a LAN configuration. FDDI standards are being developed by the American National Standards Institute (ANSI) X3T9.5 committee.

FDDI is a dual, counter-rotating Token Ring network operating at 100M-bps. The counter-rotating rings provide built-in redundancy in that should the primary ring fail for any reason, the backup ring can reconfigure itself around the downed node and continue to provide service. (See Figure 6.) This automatic reconfiguration, or self-healing, is accomplished by the station management (SMT) feature of the ANSI FDDI standard.

Optical fiber offers other advantages in addition to its 100M-bps rate and "self-healing" abilities. LAN size is definitely enhanced. FDDI allows a maximum distance between stations of 2km (1.24 miles) over multimode cable, or 40km
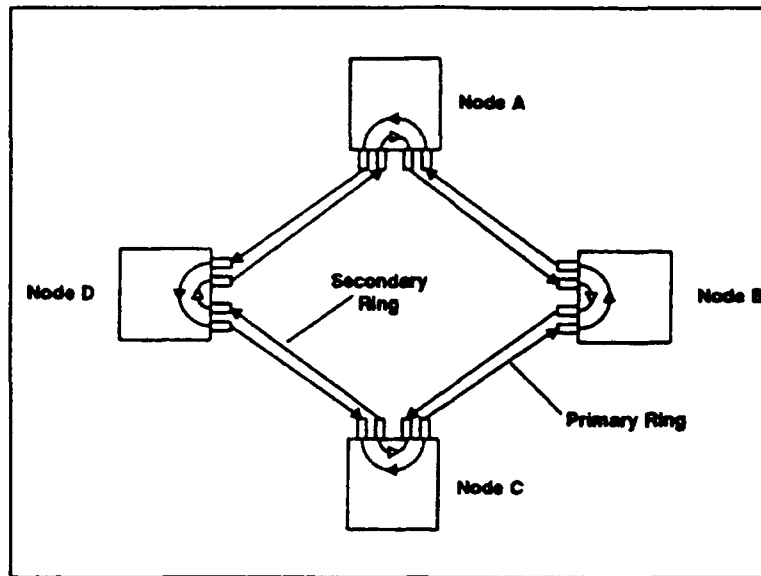
Figure 6. FDDI Ring (MALA92)

(24.8 miles) over monomode fiber cable. Maximum circumference of an FDDI dual-ring network is 100km (62 miles), permitting up to 500 stations to be attached per segment (SIMP93 p. 36).

The fiber cable requires new network interface cards (NIC) to be installed in individual nodes in order to interface with the rings. Stations attached to both rings are called dual access station (DAS), while stations attached to just one ring are called single access stations (SAS). SAS nodes are not self-healing. At the time of this writing, costs for a DAS can reach $8,800, while a SAS can run to $4,700 (SIMP93 p. 35). A third device which can be connected to FDDI rings is a concentrator. A concentrator is a device that combines data from a number of terminals onto a high-speed line (ring). The IBM 8240 concentrator can connect 24 devices to FDDI and costs $13,500 (LANM92 p. 14).

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Such steep prices for bringing optical fibers all the way to the desktop have caused FDDI to be implemented as a *backbone* network. In this way organizations can connect dispersed Ethernet or Token-Ring networks using the high bandwidth FDDI technology to increase productivity. The question then becomes at what point does FDDI become economical as a backbone network. Industry consensus is that when your current Ethernet or Token Ring backbone begins to experience an average load of 40 percent, it is time to seriously consider converting your backbone network to FDDI. It is at this point when large file transfers cause loading spikes which delay normal traffic flow (OUGH92 p. 41).

Although FDDI provides a substantially increased data rate over current Ethernet and Token Ring networks, it still has some fundamental deficiencies in its ability to support multimedia communications. The primary problem is that FDDI provides all users attached to the LAN with equal access to the LAN bandwidth. As more users begin to use multimedia applications which incorporate full motion video, bandwidth requirements will escalate and data delivery will become less predictable. It is this unpredictability which brings the latency problem to the forefront. For as is known, motion video requires the smooth delivery of picture frames with the synchronized delivery of audio.

In an effort to address such problems as jitter caused by latency delay, a new standard is being developed. Called

FDDI-II, it is a superset of the FDDI standard which attempts to resolved the problem of each user having equal access to the LAN's bandwidth. It is intended to bring a level of quality and predictability to the use of multimedia applications so that more services are available and there is a more efficient use of the bandwidth (KNAC92 p. 7).

FDDI-II provides 100M-bps of bandwidth for the network and is capable of supporting 1,200 phone calls or 75 separate video sessions simultaneously (KNAC92 p. 7). It is based upon multimode fiber optic cabling, allows 500 directly attached stations per ring and provides a bit error rate not to exceed 1 in 1 billion. An FDDI-II node can operate in one of two modes: basic or hybrid; and the ring can be configured in either mode. Basic mode means FDDI capabilities, while hybrid mode means the node or network can handle timed-token traffic and circuit switched traffic simultaneously (MAZZ92 p. 50). An important point here is that all stations attached to an FDDI-II network must be FDDI-II compatible (hybrid mode) or else the entire network can only function as an FDDI network (think of it as being able to run only as fast as the slowest player) (HOWA92 p. 78).

But it is how the network bandwidth is allocated that sets it apart from FDDI. FDDI-II is capable of allocating wide-band channels. Each channel is capable of handling 6.144M-bps, permitting a total of 16 channels on a ring. FDDI-II calls for reserving a specific amount of bandwidth for

the duration of the call (session) through the use of *isochronous communications*. IEEE defines isochronous communications as, "the time characteristics of an event or signal recurring at known periodic intervals." (WRIG90 p. 35). But this too has its drawback. The amount of bandwidth which must be allocated for the session must be equal to the peak burst rate of the transmission. This means, for example, that if 12M-bps is required for a peak burst, then a 12M-bps channel must be allocated for the duration of the session, although the average bandwidth required is lower because of the bursty nature of the transmission (RAYM92 p. 8). FDDI-II is not expected to be commercially available until the mid-1990s.

FDDI and FDDI-II, being optical fiber based systems, are meeting some resistance in implementation primarily based upon their high cost. As stated earlier, the manufacturing, installation labor, and system peripheral devices have caused FDDI to be used primarily as high-speed backbone networks rather than for node-to-node connections. Therefore vendors are seeking another way in which to implement the FDDI technology. Specifically, ways are being developed to allow FDDI technology to be used over copper-based mediums to reach the desktop.

C. **PHYSICAL TRANSMISSION MEDIA**

Having discussed the various physical and logical arrangements a LAN can assume, it is proper to consider the physical transmission media used to get the information from one place to another. Here too, there are a variety of means to transport the desired signals. An overview of each of the major media will be presented to include what new technologies are being proposed or fielded to improve their usefulness.

First however, it is necessary to understand why we have these different transmission "highways" and what is it that ultimately sets them apart. The major discriminating factor between the media discussed below is its inherent *bandwidth*. Bandwidth, measured in cycles per second or *hertz* (Hz), is the range of frequencies a medium can effectively transmit. Bandwidth has a direct relationship to the rate, measured in bits per second (bps), at which data can be transmitted from the source to the destination.

The bandwidth and data rate relationship is this: the greater the bandwidth of the transmission system or medium, the higher the data rate that can be transmitted over that medium (STAL91 37). Yet, the physical properties of each medium, or deliberate limitations of a transmitter, limit the data rate.

How then can one determine the data transfer rate, or capacity, of a given medium? A mathematician, Claude Shannon,

developed a formula, known as Shannon's Law, to determine the maximum theoretical channel capacity, or data rate:

$$C = W \log (1 + S/N)$$

where C is the capacity of the channel in bits per second, W is the bandwidth of the channel in Hertz, and S/N is the signal to noise ratio in decibels (STAL91 p. 57).

For any given medium, the greater the bandwidth, the greater the cost. Therefore economical and practical reasons dictate that information be approximated by a signal of limited bandwidth. However, limiting the bandwidth creates distortions, which makes the task of interpreting the signal more difficult. As distortion increases so does the potential for error by the receiver for properly interpreting the received signal (STAL91 p. 37). Therefore, it is important to know the characteristics of the different physical transmission media available for use on local area networks.

1. Twisted Pair Wire

Today, there are about 17.4 million installed Ethernet nodes and approximately 41.8 million are expected by 1996 (WILS92 p. 54). Although the original specifications for Ethernet call for the use of coaxial cable as the physical transmission medium, the majority of the networks were put in place using twisted-pair (TP) copper wire.

Copper wire has been traditionally favored because of its cheaper cost to manufacture and install. Although the low

cost of twisted-pair copper wire is an advantage for its use, the physical properties of this product also place limits on its ability to handle the higher data rates of FDDI. Twisted pair cable is primarily a straight-line conductor which acts like an antenna and radiates an electromagnetic field when the data, in the form of electrons, flow through it. (See Figure 7.) Just as it is capable of producing interfering wave forms, it is highly susceptible to EMI and RFI--which cause the greatest problems in attaining a quality line. The primary method for reducing the negative effects of EMI and RFI is to increase the number of twists per foot of the wire.
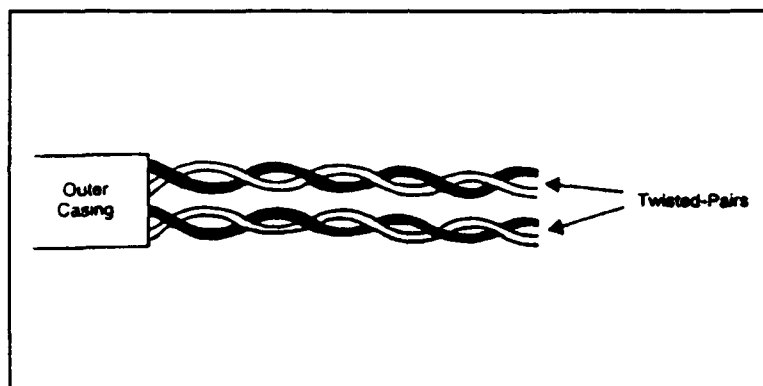
Figure 7. Twisted-pair Cable (MALA92)

Quite often in discussions concerning copper-wire cabling, one will hear references to cable categories or cable levels. The Electronics Industry Association (EIA) and Telecommunications Industry Association (TIA) have established a five-level (category) standard known as the EIA/TIA-586 standard. Of particular interest in the world of LANs, and therefore FDDI, are categories 3 and 5.

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Category 3, often referred to as voice grade (VG), cable is specified for commercial-building telecommunications wiring. It is the minimum cable for use with 10BaseT EtherNet and the minimum grade one should install for any LAN. Category 5, often referred to as data grade (DG), is the best quality UTP, demonstrating low capacitance and low cross talk, and is certified to 100M-bps (MARK93 p. 79).

When fiber distributed data interface technology is employed using copper-based cable it is referred to as copper distributed data interface (CDDI), which is synonymous with the term "*Fast EtherNet*." There are two basic categories of TP: unshielded twisted pair and shielded twisted pair.

a. Unshielded Twisted Pair

Unshielded twisted pair (UTP) is the prime source of wire used in telephone systems, and as such is used in 10BaseT LANs. It is estimated that 90 percent of the total installed base of twisted-pair wiring is unshielded. Research also reveals that of all the cable installed in 1990 and 1991, UTP moved up from 34.7 percent in 1990 to 52.9 percent in 1991 (HARR92 p. 36). Categories 3 and 5 cable are the predominant grades found in use for UTP. It is specifically the use of UTP that has caught the attention of vendors as a means of deploying FDDI technology to the desktop.

With such a well established base, vendors have devised a number of methods by which FDDI technology can be

applied to UTP. As a result, two major techniques for establishing *Fast EtherNet* networks have become accepted in the computing industry and are now being evaluated by the IEEE 802.3 committee as to which *one* will become the standard.

The first potential standard is being proposed by a group of more than 16 manufacturers, with the lead vendor being Grand Junction Networks, Incorporated. This proposed standard called *100BaseX*, favors preserving Ethernet's existing media access control (MAC) layer of CSMA/CD. The increase of speed from 10M-bps to 100M-bps would be attained by mating the MAC layer to the existing FDDI physical medium dependent (PMD) layer, as defined by ANSI. This would increase the frequency of packets sent along the LAN, while retaining the 802.3 Ethernet frame format. This increase in speed would also require the reduction in the maximum network diameters from 2,500 meters to 250 meters.

Under this plan, network interface cards (NIC) would have to be developed with processors which are able to detect if the network is operating at 10M-bps or 100M-bps. Users would then have to install these NICs and software drivers to gain the additional speed. However, this plan requires the use of category 5 (data grade) cable. Still, the argument is that by retaining the MAC protocol, 100M-bps devices can share common circuitry with 10M-bps devices, thus making it a cost effective migration path to higher bandwidth (LOUD93 p. 53).

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The second plan being proposed as a potential standard is headed up by Hewlett Packard (HP) and American Telephone and Telegraph (AT&T). Their plan would redefine Ethernet as stated in 803.2. Hp and AT&T are proposing a new MAC layer protocol called Demand Priority Access Method (DPAM) and a new signalling layer that would allow the network to run over category 3 cable (voice grade) UTP. The proposal is being called *100BaseVG*.

HP believes that because CSMA/CD was originally designed for a bus topology, it had to have the collision detection abilities that today's Ethernet networks provide. But with the advent of 10BaseT, which uses a star topology and hub-based architecture, CSMA/CD is outdated. HP and AT&T maintain that DPAM accommodates this reality by making the hub a switch instead of a repeater, thus making the network more efficient and secure (LEWI93 p. 46).

With DPAM, the hub determines which nodes will transmit and which nodes will receive, removing the need for CSMA/CD which requires the transmission of collision down to the adapter card. DPAM can also provide higher priority to real-time voice and video (multimedia), and lower priority to text and non-real-time applications (WILS92 p. 55).

100BaseVG will retain the Ethernet frame format and packet size, while using quartet signalling. Quartet signalling transmits or receives on all four pairs of cables to the desktop, dividing the signal among them at 25M-Hz each.

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The very way in which UTP is constructed, being unshielded, means it has a greater propensity for interference caused by the close proximity of electric cables, motors, air-conditioning devices and fluorescent lights. This is particularly true of the lesser grades of UTP such as category 3 (VG) cable. How then can VG cable be used to provide a reliable transmission medium? Through the use of Multi-level Transmit-3 (MLT-3).

In June, 1992 the ANSI X3T9.5 FDDI Physical Media Dependent workgroup selected MLT-3 as the encoding scheme for FDDI over UTP and shielded twisted pair (STP) wiring. MLT-3 was chosen over the competing non-return to zero inverted (NRZI) encoding scheme specified by the FDDI standard. In the NRZI scheme, when there is a transition between adjacent bits, it is interpreted as a logical 1, or "high"; when there is no transition, it is interpreted as a logical 0, or "low."

MLT-3, by comparison, uses three voltage levels or transitions. This additional step results in smaller voltage differences between steps. In essence, this additional level permits the energy to be spread out more so that it does not become powerful enough to spray emissions from the twisted pair cable (KRAM93 p. 63). In addition to meeting the Federal Communications Committee's class A (commercial) requirements, MLT-3 provides extendability to speeds up to 155M-bps (EDAT92 p. 35).

b. *Shielded Twisted Pair Wire*

Shielded twisted pair (STP) wire is most commonly associated with Token Rink LANs. In fact, the IEEE 802.5 standard specifies the use of STP for Token Ring LANs operating at 1 and 4 M-bps (STAL91 p. 429). Today, Token Ring LANs using STP typically operate at the 16M-bps rate. STP is a two-pair, 150-Ohm cable that consists of individually shielded pairs contained within an overall shield and outer jacket. This shielding, usually a form of plastic, provides both a form of protection from the environment and additional protection form the effects of EMI and RFI (THEL92 p. 26).

Just as there have been proposals to extend FDDI technology to the desktop using UTP, there is also a proposal to do the same using STP. A group of 12 vendors, led by the International Business Machine (IBM) Corporation have joined together to develop and propose to ANSI their standard, called Shielded Distributed Data Interface (SDDI).

SDDI can be supported at cable lengths to 100 meters between attaching or boosting stations. According to IBM, it does not require the complex line encoding and scramblers used to ensure data integrity in FDDI networks. SDDI is designed to operate at FDDI speeds of 100M-bps, and permit the estimated 17 million offices already wired with STP to retain the cable plants (BRAN92 p. 86). This current SDDI standard hasn't been received well by ANSI because they prefer to develop one standard for both STP and UTP (GILL92 p. 1).

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2. Coaxial Cable

Coaxial cable, commonly referred to simply as "coax", is similar to twisted pair cable in that it too has two conductors. What sets them apart however is how the two conductors are constructed into the cable. Coax consists of a hollow outer cylindrical conductor which surrounds a single inner wire conductor. The outer conductor can be either solid or braided, while the inner conductor can be either solid or stranded. The two conductors are separated by either spaced insulating rings or a solid dielectric material (STAL91 p. 64).

Coaxial cable has long been a standard for long distance telephone communications because of its ability to carry 10,000 voice channels simultaneously through frequency division multiplexing. However, it is being rapidly replaced by optical fiber, microwave, and satellite. Coax is becoming a more common sight in the home because of the boom in cable television service. Originally designed as a means to provide TV to remote areas through the Community Antenna Television (CATV) service, cable TV may eventually reach as many homes as the telephone (STAL91 p. 64).

Capable of providing a total data rate of 500M-bps with a bandwidth of 350M-Hz, coaxial cable can support a variety of data and traffic types and is a viable medium for

local area networks. Coax can be configured into either baseband or broadband LANs (STAL91 p. 59). (See Figure 8.)
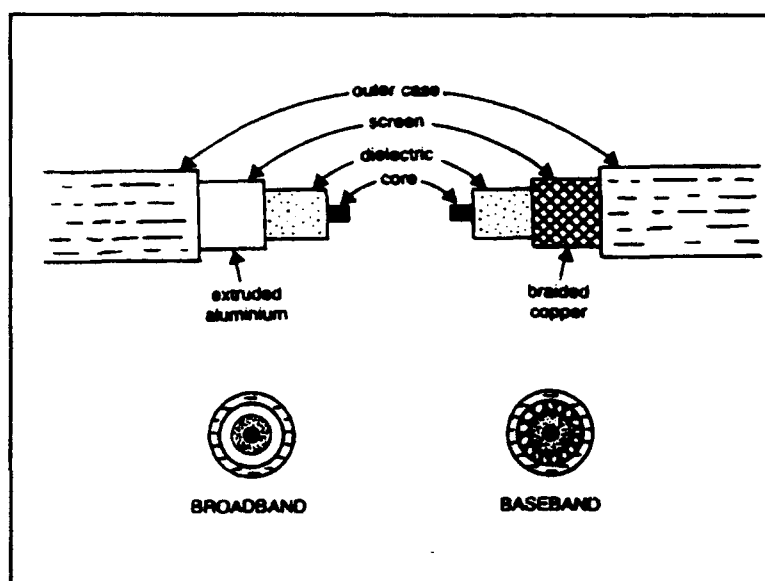
Figure 8   Coaxial Cable Types (MALA92)

a. Baseband

A baseband LAN is defined as one that uses digital signaling. Digital signals are inserted on the line as voltage pulses. Because the entire frequency spectrum of the medium is used, frequency division multiplexing (FDM) cannot be used. Transmission of the signal is bidirectional: a signal inserted at any point on the medium is propagated in both directions. Baseband coax is designed for bus topology networks.

Most baseband coax systems use a special 50-ohm cable rather than the standard 75-ohm CATV cable. 50-ohm cable provides less intense reflections form the insertion of the taps and provides better immunity against low frequency EMI.

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IEEE 802.3 standard for 10Base5, *thick* EtherNet, specifies the use of 50-ohm cable with a diameter of 0.4 inches, and a data rate of 10M-bps. The 10Base2, *thin* EtherNet, standard specifies a 50-ohm cable with a diameter of 0.25 inches, and a data rate of 10M-bps (STAL91 p. 384).

b. Broadband

In the context of LANs, broadband refers to the use of analog signaling; therefore FDM is possible. This permits the frequency of the cable to be divided into channels or sections of bandwidth which can support data traffic, TV, or radio signals. Broadband components allow splitting and joining operations, supporting both bus and tree topologies.

Broadband systems use standard CATV components, to include 75-ohm coaxial cable capable of a 450M-Hz bandwidth (STAL91 p. 389). Broadband systems are inherently unidirectional, meaning the signal, once inserted on the medium, travels in only one direction. Because only "down stream" nodes can receive the signal, two data paths are required to ensure all stations are reachable.

The point at which the two paths are joined is known as the *headend*. For a bus topology, the headend is simply one end of the bus. For a tree topology, the headend is the root of the branching tree. All stations transmit on one path toward the headend (inbound). Signals received at the headend are then propagated along the second path away from

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the headend (outbound). All stations receive on the outbound path. These inbound and outbound paths can be achieved by using two physically separate cable runs operating at the same frequency, or one cable run can be used which has two frequency bands (STAL91 p. 388).

3. Fiber Optic Cable

Fiber optic cable, also commonly referred to as optical fiber, is the best *guided* transmission medium known to exist. An optical fiber is a strand of very fine glass thinner than a human hair and is capable of data rates of 2 giga-bits (giga = 1 billion or 10") per second (G-bps) over tens of kilometers (STAL91 p. 67).

Optical fiber has a cylindrical shape and consists of three concentric sections: the core, the cladding and the jacket. The *core* is the innermost section and can be made of various glasses or plastics. Ultrapure fused silica fiber provides the lowest losses but, it is difficult to manufacture and is therefore expensive. Multicomponent glass fibers are more economical and still provide good performance. Plastic fibers are even less costly, and are only good for shorter length links where moderately high losses are acceptable (STAL91 p. 65).

Each fiber is surrounded by its own *cladding*, also made of glass or plastic with a lower refractive index than the core. The *jacket* is the outermost layer surrounding one or

a bundle of cladded fibers. The jacket is made of plastic or other materials and is designed to protect the optical fiber from environmental dangers (STAL91 p. 67).

Fiber optic cable carries a pulse(s) of light generated by either a light emitting diode (LED) or an injection laser diode (ILD), commonly referred to as a laser. An LED is less costly, operates over a greater temperature range, and has a longer operational life. The laser is more costly, more efficient and can sustain a greater data rate. The optical fiber acts a waveguide for frequencies in the 10^{14} to 10^{15} hertz range, which covers the visible spectrum and part of the infrared spectrum (STAL91 p. 68).

While optical fiber's ability to transmit data at a much higher rate is a particularly strong argument for its use, another enticing advantage is its smaller size and weight. A cable with several hundred pairs of copper wire may be 2 or 3 inches in diameter, while a fiber optic cable of equal capacity may be less than 5 millimeters in diameter (HOUS87 p. 333). Such a dramatic difference in size decreases the supporting structure requirements. The physical properties of fiber optics provide enhanced security because fiber can't be tapped into without being detected, nor does it emit an electrical field which can be monitored by unauthorized devices. Optical fiber is also immune to electromagnetic interference (EMI) and radio frequency interference (RFI) which degrade the signal quality.

Drawbacks to the use of optical fiber includes its high cost to manufacture and install. Manufacturing costs are a result of the high technical requirements associated with producing the more exotic optical fibers in a varying degree of purity. Fiber cable can cost from 41 cents per foot to $1.40 per foot depending upon the mode and core material. The installation labor costs $45 to $60 per hour, and each fiber loop takes an average of three hours to install (ROSA92 p. 42). Installation is difficult because fiber is much less flexible than copper wire, and the effort to terminate a fiber run requires exacting measures to ensure the light rays can be sensed at the end of the fiber.

There are three modes of transmission for light transmitted through optical fiber.

a. Multimode

When light from a source enters a glass or plastic core, rays of light propagate along the fiber. Rays entering at a shallow angle travel down the core while rays of a steeper angle are absorbed by the surrounding material of the cladding. The various shallow angle light rays provide the name for "multimode", and each ray represents a different path with its own length and therefore its own time to traverse the cable. These different path lengths cause the signal elements to spread out in time and limit the data rate. Multimode fiber is typically used for computer data links and LANs, and can

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have either a LED or laser as its light source. (See Figure 9.)
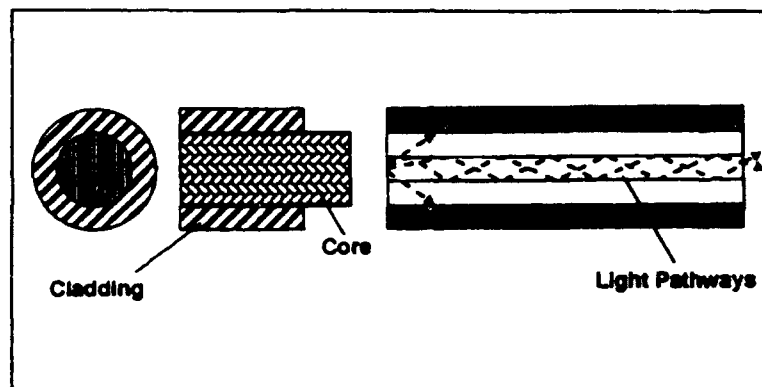
Figure 9.   Multimode Fiber Optic Cable
(MALA92)

b. *Monomode*

By reducing the radius of the fiber core, fewer light angles will reflect down the cable. If the radius of the core is reduced to the order of a wavelength, only a single or mono-angle can pass. This single transmission path offers no distortion. Therefore the bandwidth of a monomode fibre cable can reach to 1000 Ghz/km, which means a much higher data rate. Monomode fiber cable is typically used for long distance telecommunications lines, and supports the higher signalling rate only a laser diode can provide.   (See Figure 10.)

c. *Graded Index*

The third type of optical fiber is an intermediate of the monomode and multimode. By varying the index of refraction of the core one can focus the rays of light more efficiently. This is known as the multimode graded index or

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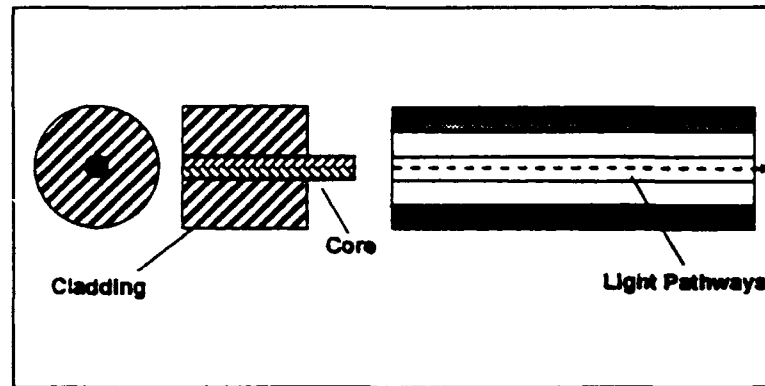
Figure 10. Monomode Fiber Optic Cable
(MALA92)

step index, and is typically used for moderate length
telephone lines. Either a LED or a laser can be used as the
light source for a graded index fiber. (See Figure 11.)
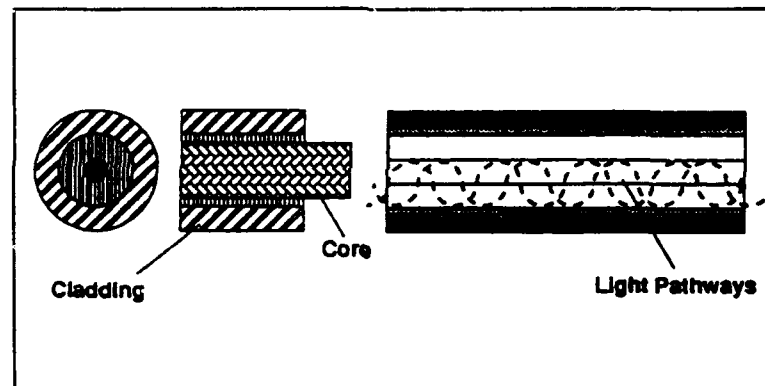
Figure 11. Graded Index Fiber Optic
Cable (MALA92)

4. Radio Frequency - Wireless

All of the transmission media discussed so far have be
the *guided* media variety. Radio frequency, or wireless LANs
use *unguided* media, and are discussed in detail in Chapter IV.

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D. ALTERNATIVES TO AVOIDING NETWORK BOTTLENECKS

The discussions above concentrated on FDDI and FDDI-II as a means to increase LAN, and LAN backbone bandwidth and data rates to handle the increased requirements of bandwidth intensive applications such as multimedia. There are, however, numerous discussions within the computing and communications industries as to what is the best way to meet these expanding bandwidth requirements. What follows is a look at a method of enhancing existing LAN systems, a new proprietary technology for supporting video transfer to the desktop, and one technology for preparing for future growth beyond FDDI based solutions.

1. Segmentation of Local Area Networks

Optical fiber based LAN technology such as FDDI and FDDI-II are immature technologies that are not yet fully standardized and carry a large price tag for what many firms still consider questionable benefits. However, organizations are experiencing growing demands on their LAN's bandwidth as more people are making the computer their working tool of choice. This increase in the number of nodes on a LAN, coupled with the growing file size and bandwidth appetites of more sophisticated applications, is having negative consequences in the form of decreased responsiveness and reliability. Network managers who are still caught with the twin mandates of enabling user productivity while remaining cost conscious will

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be faced with premature cabling/wiring upgrades (LUCZ92 p. 100).

Segmentation of existing LANs is a viable solution to these problems. As the number of nodes on a LAN grow, the responsiveness and reliability of the LAN begin to deteriorate. By studying the usage patterns of the network, managers can determine who the major users are, and begin to build a profile of how best to segment the LAN. Segmentation should take place so that those users who communicate together most often are placed on the same segment. Segmentation in this manner can minimize or perhaps even delete the requirement for data transfer between segments. Smaller segments have full original LAN bandwidth, but the bandwidth is being used by fewer nodes, applications or devices.

How then is such segmentation accomplished? By using bridges, a device which forwards and filters packets depending upon their destination address, one can isolate a segment from the backbone network. By minimizing cross-backbone traffic, the efficiency of the backbone is increased, thereby, perhaps, delaying the need for a backbone upgrade (say to FDDI).

Also quite popular today is the use of wiring hubs. Originally wiring hubs were installed together in the "wiring closet", and connections or changes had to be made manually to the hub. Today hubs are made programmable, or "intelligent" through the use of software.

Sometimes referred to as LAN switches or "backbone-in-a-box", intelligent hubs permit the network manager to reconfigure the segments as required from a desk rather than having to go through the laborious task of pulling and plugging wires. Such an ability allows a more efficient and effect use of the LAN's bandwidth. Because packets are forwarded without first being buffered, LAN switches have a relatively low latency, measured in the tens of milliseconds (SMAL92 p. 33).

The main advantage and attraction of this method of using these devices is that they preserve a site's existing network investment in equipment, training and procedures while boosting overall bandwidth. However, whether these devices will be able to provide the kind of performance most networks will require by the mid-1990s to support such applications as multimedia is not yet known (SMAL92 p. 34).

2. Starlight Networks Incorporated: StarWorks

Starlight Networks Inc., has developed a means to provide full-motion video over an Ethernet LAN in a 10BaseT topology. Based on a dedicated video server operating with proprietary software to control the flow of video data, it is capable of providing video images at the rate of 30 frames per second to up to 20 users simultaneously.

StarWorks requires the use of a dedicated video server to manage video related tasks. Starlight can provide a

customer with its MediaServer video server which is based on a 50M-Hz 486 based Extended Industry Standard Architecture (EISA) server with either 3 or 6 giga-bytes of storage and 16 mega-bytes of random access memory (RAM). The StarWorks proprietary software permits simultaneous access to the same video file, or many video files, by storing them across several Winchester drives. This permits several users to view the same video clip, even though they've all started the clip at different times (CHER93 p. 80).

MediaServer is capable of putting data onto wires at a 25M-bps rate, translating, for example, to 20 clients running video at 1.25M-bps or four clients running video at 6M-bps. These transmission speeds are made possible by using a combination of Joint Photographer Experts Group (JPEG), Motion Picture Experts Group (MPEG), and digital video interactive (DVI) compression techniques which compact video from 30 frames per second to 16 frames per second for transmission, then decompresses the image on the personal computer (GREE92 p. 32).

For StarWorks to be most effective, it must be implemented on networks which have be segmented into the closest possible working groups and uses switching hubs to provides 10M-bps bandwidth to the desktop. StarWorks is currently available in two versions. StarWorks-12 can support up to 10 users at 1.5M-bps and has six hours of video storage.

StarWorks-25 can support up to 20 users at 1.5M-bps and has 12 hours of video storage (MULT92 p. 1).

3. Asynchronous Transfer Mode

Asynchronous Transfer Mode (ATM) is an emerging technology that has the potential to solve the LAN bandwidth problems posed by the use of multimedia applications. ATM is not a medium like optical fiber or copper per se: it is a technology not a product, but it forms the basis for different types of products such as a switch.

ATM was designed to eliminate the wasted bandwidth associated with dedicated channels for a certain type of data; voice, video, or data for example. To illustrate, a voice channel typically requires 32 to 64K-bps. When a person is not speaking, however, he or she requires zero bandwidth. During normal speech there are many pauses in conversation and between words, thus wasted bandwidth on the circuit. Data and video traffic are also bursty in this same manner (MALA92 p. 77).

ATM takes all of this traffic and splits it up into small cells. Two ATM devices communicate with a constant stream of cells. If someone has traffic to send, the cell carries traffic. If not, no cell is transmitted. An ATM switch thus ·cepts traffic from a variety of users. Because the cells are small, the switch is able to provide statistical

multiplexing for different data sources over a single physical link (MALA92 p. 78).

Workstations with the appropriate ATM equipment will be able to transmit their data in 53-byte cells: 5-bytes of header information and 48-bytes of data. This cell size is standardized by the international telecommunications standards committee (CCITT) and forms the basis for Broadband Integrated Services Digital Network (B-ISDN). B-ISDN is specifically designed for real-time multimedia connections in the public telephone network (THET90 p. 31).

Because of the fixed cell size, network delays and latencies can be predicted, making ATM suitable for carrying real-time information. In comparison, LANs use variable length packets, which makes delays unpredictable and unsuitable for carrying voice and video. ATM operates at speeds from 1.544M-bps to 1.2G-bps with several specified interim speeds. LAN speeds are anticipated to be at 155M-bps (SCHT92 p. 21).

ATM may make its appearance in several places on your network. On the desktop, workstation vendors will equip their machines with ATM interfaces in the same way Ethernet or FDDI are used today. Network hub manufacturers are evolving their products from using a bus-based architecture (usually several Ethernets, Token Rings and/or FDDIs) to a switch. This change will enable them to achieve higher throughput and support new applications and larger networks (SCHT92 p. 23). Telephone

companies plan to install ATM capable switches as part of their public switched networks.

CHAPTER IV WIRELESS COMMUNICATIONS

While the communications services provided by the various *guided media* covered in the previous chapter have many benefits, they are lacking one very important ability. Their very nature of being a physical media means that they must be hard wired into a set configuration. While these configurations are not necessarily permanent, they do not lend themselves easily to reconfiguration.

Personal and personnel mobility is seen as a key ingredient to increased creativity and productivity. The ability to freely move about, whether within an office, building, city or larger area is being viewed by a growing number of businesses as a competitive advantage. Such an advantage is made possible through the use of wireless communications methods.

In this chapter we will look at the various wireless, or *unguided media* technologies available today and planned for future deployment, and evaluate their ability to support multimedia computing in a mobile environment.

A. TYPES OF WIRELESS COMMUNICATIONS SERVICES

1. Cordless Telephones (CT1)

There are over 30 million cordless telephones in use today in the United States, and it is estimated that about one

half of all residential phones purchased in the following years will be cordless models (WICK90 p. 94). Their low unit cost ($50-$100) and lack of a monthly usage charge are significant features leading to their popularity.

Cordless telephones use analog technology and operate in the 46/49M-Hz frequency band, which is not a dedicated spectrum. What this means is that they are permitted to be used on a not-to-interfere basis with other devices operating in this same frequency range (WICK90 p. 94).

Frequency interference is not a concern with cordless phones because their small power requirements limit their transmitting distance to 700 feet (VIZA91 p. 33).

2. Cellular Telephone

Since their introduction in 1983, Cellular telephones have become very popular throughout the U.S. and the world. Today there are approximately 8 million cellular phone users in the United States. With unit costs between $300 and $1000, and monthly usage costs about $90, they are not economically feasible for everyone (MART93).

Today's cellular phones are primarily of the analog variety, although digital cellular phones are being introduced in larger number because of their increased capabilities. The Federal Communications Commission (FCC) has dedicated a portion of the radio frequency spectrum in the 824-849M-Hz and 869-894M-Hz range for cellular telephones (WILK91 p. 51).

Current analog cellular phones operate within average cell sizes of 6 miles, and are capable of two-way calling, roaming, and handoffs. Roaming means that one is not limited to placing or receiving a call in one particular cell. Handoffs, or handing-off, refer to the ability of a person to move from cell to cell while maintaining an in-service connection. Analog cellular phones are capable of data transmission via cellular modem, but the data rates are limited to around 2400 baud due to the need for sophisticated error control (MART93).

Analog configured phones are nearing the subscriber saturation point. By switching to digital technology, the number of subscribers that can be handled per cell is expected to increase three fold initially, and up to 10-fold later. (WICK90 p. 94) Additional benefits of digital cellular phone include clear reception due to less cross-talk and fewer dropped calls. Dual-mode phones capable of both analog and digital operation are available.

While all current cellular telephone networks, be they analog or digital, use ground-based radio repeater sites to implement area coverage (cells), the Motorola Corporation (USA)˙ is proposing a more provocative concept they call *Iridium*. Motorola plans to launch a network of low orbiting communications satellites. Operational orbit for Iridium satellites would be 500 miles, a sharp contrast to a

geosynchronous communication satellite orbit of 23,000 miles (WICK90 p. 96).

Satellites supporting the Iridium concept would be, in essence, sky-borne cellular base stations. Iridium would provide cellular (PCN/PCS) type services to locations around the world where traditional cellular service is unavailable or impractical (WICK90 p. 96).

3. Cordless Telephone-Second Generation (CT2)

The second generation of cordless telephones (CT2) or as it is also commonly known, Telepoint, is a European Telecommunications Standards Institute (ETSI) interim standard. ETSI decide to make CT2 an interim standard while awaiting the arrival of the Digital European Cordless Telecommunications (DECT) standard.

The British, with the aid of the British government who dedicated the 864-868M-Hz band, made CT2 commercially available in 1989. CT2, which will support 12,000 simultaneous users per square mile, provides one voice channel using frequency division multiple access (FDMA), at a bit rate of 32 kilo-bits per second (K-bps) (WILK91 p. 51).

FDMA is a mature technology and can support either analog or digital operations. Under FDMA, the frequency band is divided into segments and each segment is assigned to a single user. A problem with this method is that FDMA is inflexible to increased traffic loads (FREE91 p. 403).

There are a number of criticism concerning CT2. It is a one-way only service. A person can originate calls but cannot receive them. The limitation of one voice channel per call means that there is no provision for bandwidth on demand or variable data rate applications. CT2 is also incapable of roaming and call handoff which severely limits its utility.

4. Cordless Telephone-Second Generation-Plus (CT2+)

In an effort to remedy the criticisms leveled against CT2, its proponents developed an updated version they termed CT2+. Virtually technically identical to CT2 except that it will operate in the 930-931M-Hz and 940-941M-Hz band, it will notify users via a pager/beeper-type signal when incoming calls are received.

CT2+ will also provide the ability to "roam" from one carriers's cell to another's because of the adoption of a Common Air Interface (CAI) standard in Europe, referred to as Spec. MPT 1375. However, one problem that still won't be solved is the lack of ability to "hand-off" a call that's in progress from one cell to another (WICK90 p. 98).

5. Digital European Cordless Telephone (DECT)

DECT is an emerging European standard that operates in the 1880-1900M-Hz (1.88-1.9G-Hz) band, and can provide 12 full-duplex voice channels per frequency channel by either FDMA or time division multiple access (TDMA).

TDMA operates in the time domain and is applicable to digital systems only. Each carrier (a specific frequency-centered channel) is subdivided into timeslots. Each caller receives both a transmit and a receive time slot. TDMA provides variable data rates of 32 to 736k-bps (WILK91 p. 51).

Other advantages of DECT include two-way calling, support for roaming, and the potential for call handoffs (this feature may not be available in the first DECT standard). With the use of TDMA and tight power level control, DECT will be able to support more users in a smaller geographic area, with estimates of 20,000 to 200,000 simultaneous users per square mile (WICK90 p. 98).

B. PERSONAL COMMUNICATIONS NETWORKS

1. What are Personal Communications Networks?

Personal communications networks (PCN) aim to provide the ability to reach a person, rather than reaching a place. PCN is a technology based on radio transceiver (cellular telephone) networks that will permit the assignment of *one* "phone number" to a *person*. Ultimately, a person would be able to be contacted using this one number no matter where they may be: at home, in the car, in the office, across town, or across the globe. PCN is an emerging strategy based upon evolving cellular telephone technologies.

Under the PCN scheme are found a variety of services, called personal communication services (PCS). Such services

would include paging, telephone service to include call forwarding and call screening, and data transmission service to include electronic mail or data file transfer, to name just a few. One should be aware that the terms PCN and PCS are often used interchangeably.

PCN is a reality today, but is only in its early stages. Europe, especially Britain, is the leader in establishing PCNs, and Canada is also very active in the field. America, although well organized with cellular telephone networks, has not done much to extend such networks to encompass PCN technologies. There are a number of reasons for this, which are explained below.

2. PCN From a United States Perspective

Although Europe and Canada are making fast inroads to implementing PCN and PCS technologies, the United States is taking a different tack. Reasons for our apparent delayed jump onto the PCN bandwagon are both politically and technologically driven.

a. The Politics of PCN

The United States Congress, Federal Communications Commission (FCC), and the Department of Commerce's National Telecommunications and Information Administration (NTIA) are all actively involved in wireless rule making. Such high level interest is due to the fact that the radio frequency spectrum

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is both a national and a limited (finite) resource, and must be carefully regulated.

Whenever the issue of frequency reallocation is brought up, powerful lobby groups respond in heated protests because of the high cost of equipment change outs. Interested parties in such considerations include protection services such as police and firefighters, railroad companies, and utility companies (to include communications companies) to name but a few.

The 1880M-Hz to 1990M-Hz band is what is being targeted as the PCN band in the U.S. This causes a large problem however because this is the same band that is currently allocated to more than 8,100 non-government fixed service users, particularly point-to-point microwave users such as railroads, power, petroleum and common carriers (WILK91 p. 51).

Even when the question of what the spectrum band will be is answered, another equally troublesome question will be how to assign the spectrum and to control it. NTIA advocates a market based spectrum allocation as opposed to allocations based upon a lottery or comparative hearings. Under this scheme, a license would confer some property rights that could be bought and sold. An interesting note to this is that although current law doesn't provide for such a scheme, the Federal budget includes a line item for the income from the auctioning of spectrum (WILK91 p. 51).

NTIA argues that by selling the spectrum, the marketplace could establish the real worth of the band. Such an incentive could also prod Federal agencies to release spectrum for private use. The FCC has called for open competition among cellular, telephone, and cable television companies as a replacement for rate regulation. NTIA estimates the aggregate spectrum value to cellular license holders is between $46 and $80 billion (WILK91 p. 52).

The FCC adopted a rule which is called Part 15 of the FCC rules. This landmark decision authorized the use of certain frequencies bands on a "shared-use" basis (1850 to 1990M-Hz for emerging technologies such as PCN). The shared-use provision recognizes that there are primary and secondary users in all Part 15 bands. It stipulates that if a secondary user generates any interference with any primary user, the secondary user is obligated to cease operation. Such a rule places a rather large caution sign in the face of potential corporations to research and develop PCN/PCS systems because they may have to cease operation of capital intensive programs (QUIN92 p. 46).

b. *Technical Aspects of PCN in America*

American corporations conducting research and development of PCN/PCS systems are using a channelization method known as spread-spectrum transmission or code division multiple access (CDMA).

Initially, CDMA was only attractive to the military because of its antijam and low probability of intercept properties which provide security from intercept by unauthorized users. With CDMA, the transmitted signal is spread over part or all of the available bandwidth in a time-frequency relationship by a code transformation (FREE91 p. 395).

Since 1980 some interest in CDMA has been shown in the commercial sector for demand access for large populations of data circuit/network users with bursty requirements in order to improve spectral utilization. The "spreading" of the signal minimizes the effects of extraneous interference on the composite signal, as well as the signal's potential to interfere with other transmissions in the same frequency band (WICK90 p. 97).

The ability to minimize mutual interference is a critical feature of the CDMA technology. In addition to the political considerations mentioned above, there are some basic technical reasons why PCN needs to operate in the 1.85G-Hz to 1.99G-Hz spectrum range. Beyond about 2.4G-Hz, power requirements become excessive and the components necessary to generate such frequencies are more expensive. Also, as a general rule, the higher the frequency the shorter the transmission distance. Below 800M-Hz, antenna size becomes a practical obstruction (WICK90 p. 98).

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C. **WIRELESS LOCAL AREA NETWORKS**

Another area in which wireless communications technology is becoming wide spread is in local area networks (LAN). Often times such a combination is referred to as wireless local area networks. IEEE has established the 802.11 committee, the largest of all IEEE committees at 130 people, to oversee the establishment of wireless standards.

Wireless LANs are becoming more popular because of their ability to enable people to move about within an office or building and quickly access the network. Such a capability permits people to go to and stay at those places where they are most needed while retaining access capabilities to computerized information, thereby enhancing creativity and productivity.

Wireless LANs are also viewed as a cost-cutting or cost-saving method in expanding or contracting existing hard-wired LANs. Research has shown that the average worker will move within an office or building at least once a year. To track such flow patterns on a traditional LAN involves more than just administrative work, it often includes the physical relocation of cable runs. Wireless entry points into the LAN eliminate the need to modify cable layouts, a time consuming and expensive proposition.

Two types of systems have made wireless LANS possible: spread-spectrum and infrared.

1. Spread-Spectrum

Spread-spectrum technology, also known as Code Division Multiple Access (CDMA), was explained earlier in section B.2.b of this chapter. The characteristics, capabilities and limitations of CDMA in a PCN hold true for its use in a wireless LAN.

Current CDMA based wireless LANs operating at 915M-Hz are capable of 2M-bps data rates for distances of up to 400 feet and can accommodate as many as a hundred workstations. With special hardware attachments, transmission distance can be extended up to 5 miles (COMP91 p. 1).

2. Infrared

Infrared technology enables transmission of signals via laser diodes for point-to-point networking and light emitting diodes for point-to-multipoint systems.

Transmission rates for infrared based wireless LANs can reach up to 16M-bps for token based systems, but their transmission distance is severely limited, sometimes to as little a 30 feet. These system are highly line of sight dependent, which makes them impractical in many office environments (COMP91 p. 3).

3. Altair

The Motorola Corporation has fielded their Altair wireless network in Germany and Spain. By using intelligent antennas and low-power millimeter waves in the 18 to 19G-Hz

band, Altair is based on the company's Wireless In Building Network (WIN) system which currently follows Ethernet protocols. WIN uses spread-spectrum technology and can send data at speeds up to 15M-bps (COMP91 p. 5).

While wireless LANs certainly have their place in the computer and communications arena, there doesn't appear to be any possibility that they will replace hard-wired LANs.

Capital investment in current LAN systems is too overwhelming to justify their removal or discontinued use. Although wireless LANs provide an important benefit, especially in flexibility, they are still somewhat expensive and don't yet match the speed and distance characteristic of traditional LANs. The future of wireless LANs appears to be as an augmentation to current architectures rather than as a replacement.

D. WIRELESS COMMUNICATIONS FOR MULTIMEDIA

Can wireless communication technologies support multimedia information exchange? In order for a technology to be able to provide such support it must satisfy two conditions: sufficient bandwidth and an isochronous channel. Table 1 below summarizes the various wireless technologies and their associated data transfer speeds.

TABLE 1. DATA TRANSFER SPEEDS OF WIRELESS TECHNOLOGIES

Wireless Communications	Analog Cellular	2,400 baud
	Digital Cellular	32k-bps
	CT2	8k-bps
	DECT	32 - 736k-bps
	PCN	6.7k-bps
Wireless LAN	Spread Spectrum	2,000k-bps
	Infrared	16,000k-bps
	Altair	15,000k-bps

All wireless communications services, except for wireless LANs, provide a dedicated channel for the duration of the call. Thus, latency is not a problem, and they can support the transfer of multimedia information.

Wireless LANs, however, involve the use of some form of medium access control mechanism (CSMA/CD or token), possibly causing variable delays in data transmission times. For this reason, wireless LANs may have a limited capability for multimedia, just as traditional hard-wired LANs.

V. LONG HAUL COMMUNICATIONS

To this point we have looked at the various guided and unguided transmission media available for the transfer of multimedia information over a relatively limited distance. In this chapter we will investigate what services are available to permit the transmission of multimedia information over greater ranges.

A. SWITCHED SERVICES

When discussing switched networks one usually envisions the public telephone network, operated by a *communications carrier* or *common carrier*, for voice communications. However, as will be shown, switched services can support a number of different information formats.

1. Circuit Switched Network

The most common example of a circuit switched network is the telephone network. In a circuit switched environment a dedicated communications path is established between two stations (phones, computers, facsimiles, etc.). The path is a connected sequence of links between nodes (switches). On each physical link, a channel is dedicated to the connection.

The establishment of an end-to-end connection via circuit-switching occurs in three phases: 1) an end-to-end circuit is established via switching nodes; 2) data is

transferred over this dedicated circuit, and; 3) the circuit is released upon the request of either station. A node is either an electronic or electro-mechanical switching device that transmits bits as fast as it receives them.

Note that the connection path must be established before any data transfer can begin. Thus, channel capacity must be reserved between each pair of nodes for the duration of the connection. This results in circuit switching being a rather inefficient system because channel capacity is dedicated even if there is no data being transferred.

Voice communications produces the greatest amount of inefficiency in circuit-switched networks since the voice channel is mostly idle. Circuited switched networks are good for the transfer of bulk data. However, because its channel capacity is set upon establishing the circuit, circuit switched networks are inefficient for bursty traffic assoc..ted with "interactive" multimedia information.

2. Message Switched Network

An alternative approach to having nodes immediately send data bits to the next node as soon as they are received is to exchange logical units of data, called *messages*. Examples of messages are telegrams, electronic mail, computer files and transaction queries and responses.

It is not necessary to establish a dedicated path between two stations in a message switched network. Rather, a

message is sent from node to node in a *store and forward* fashion; i.e., at each node, the entire message is received, stored briefly on disk, and then forwarded in its entirety to the next node.

Although message switching has many advantages over circuit switched networks, such as its ability to send a message to numerous destinations simultaneously and inherent error control and recovery procedures, it is not suited to realtime or interactive traffic. The delay at each node in the network is relatively long and highly variable, primarily because there is no limit on the size of the message. Such latency characteristics makes it unsuitable for voice traffic, and thus it is also an inappropriate method of transferring interactive multimedia information which is highly time and sequence sensitive.

3. Packet Switched Network

Packet switching is an attempt to combine the advantages of circuit switching and message switching, while reducing the disadvantages of both. A packet switched network consists of a number of computer based switching centers which are interconnected via high-speed communication lines (the lines can be either analog or digital).

Packet switching differs from message switching in that the size of the message, called a *packet*, is limited. Packet size is established to be between 1000 and a few

thousand bits, with a typical packet size being 1024 bits. If a message is longer than the established packet size, it must be broken up into separate packets and sent out one at a time. By limiting the size of the packets, they can be buffered into the node's main memory rather than being transferred to disk. Packets can also be forwarded to the next node before a following packet is received.

Packet switching also improves the efficiency of the use of the transmission lines. Rather than dedicating a line to a single user as in a conventional circuit switched network, packet switching permits information from unrelated sources to be sent to unrelated destinations over the same line.

There are two methods for handling separate packets belonging to a single message.

a. Datagram

In the datagram approach each packet is treated independently, similar to how each message is treated independently in a message switching network. Each packet has a destination address attached which permits the network to route the packet via the most expeditious nodes and links to its destination.

Because packets may travel over different routes, they may arrive at their destination in a different sequence than which they were sent. The reordering of packets into

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their correct sequence can be done either at the last node in the path or at the receiving station itself.

Datagram processing is advantageous for messages broken up into a few packets because end-to-end call setup is not required. Each node makes the routing decision based upon the network situation at the time of receipt of the packet, based upon network congestion or link outages. This also provides an inherent reliability factor because packets will not be sent to an inoperable node, thus avoiding lost packets.

b. *Virtual Circuit*

A virtual circuit (or virtual call) is a *logical* point-to-point connection that is established between the sending and receiving terminals before any data is sent. In contrast to the datagram method were each node must make a routing decision, the routing decision is made once, thereby reducing the data transfer delay time between nodes.

In a virtual circuit system, the packet switching network delivers packets in the order in which they were received by the network.

In addition to ensuring packets arrive in the correct sequence, a virtual circuit facility *may* provide error control and flow control services. *Error control* ensures that packets arrive in the proper sequence and are error free. If an error is detected, a request for the retransmission of the bad packet is sent to the previous node. *Flow control* is a

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technique that ensures the sender doesn't overwhelm the receiver with data. If a node detects that it is running out of buffer space, it can request that the sender suspend transmission until further notice. Error and flow control are not found in datagram-based, packet switched networks.

By limiting the size of the data into packets and permitting the forwarding of packets without the entire message being received, network performance is dramatically enhanced. Thus the processing delay at each node can be minimized, making packet switched networks suitable for real time or interactive traffic. However, it is generally held that packet switched networks are inappropriate for voice and multimedia information because of variable delays.

4. Fast Packet Switching

Fast packet switching (FPS) is a newer switching technology designed primarily for data communications at speeds from 1.5M-bps to 2.5G-bps. FPS is a set of *streamlined* packet switching technologies that provide reduced protocol processing (high throughput and low delay) while retaining the advantages of packet switching (efficient use of transmission facilities). FPS typically requires the use of dedicated or *leased lines* to connect to the network.

The "streamlining" aspects of FPS are associated with the fact that the high quality and speed of modern digital transmission trunks, such as optical fiber cable, eliminates

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the need for error and flow control on a per-link basis (SUH92 p. A1) Also, rather than establishing a virtual circuit on a call-by-call basis as is done for packet switched virtual circuits, one is able to have the network operator administratively set up a *permanent virtual circuit* via the network management system. In essence, this is a virtual circuit which is always in the data phase, the connection is never broken (HOUS87 p. 366).

The purpose of this "streamlining" is to overcome the traditional weakness of traditional packet switching; large delay and variable delay. FPS includes frame relay and cell relay. *Frame relay* is based upon variable length frames of data. *Cell relay* is based upon fixed length cells of data.

Fast packet switching is becoming commonly referred to as *broadband packet*. Broadband packet switching is a specialized form of packet switching and multiplexing. The use of the word "broadband" implies that the technologies are appropriate to be used at "broadband speeds," that is, at T1 (1.544M-bps) and higher. Broadband packets are fundamentally the same as other types of packets, consisting of a header, a payload, and optionally, a trailer.

There are three types of broadband (fast) packet networks: Frame relay, switched multimegabit data service (SMDS), and asynchronous transfer mode (ATM). All three types of broadband packet networks have in common the assumptions that the transmission facilities will be "clean" (very low

error rates), and the traffic handled will be protocol-oriented data. "Clean" facilities preclude the need for link based error and flow control, while inherent protocol in the traffic will guarantee delivery, so the network need not perform this task. These assumptions allow the network to bypass processing tasks that guarantee delivery, thus accelerating throughput (TAYL93 p. B4).

a. Frame Relay

Frame Relay defines an efficient scheme for moving variable length data packets between local area networks (LAN) and wide area networks (MAN). Whereas Frame Relay is typically associated with T1 speeds, it can technically achieve T3 (45M-bps) speed.

Frame Relay is connection oriented, meaning that it builds virtual circuits, or logical paths, through the network. In particular, Frame Relay uses permanent virtual circuits (PVC). PVCs behave like traditional leased lines in that they have fixed end points that are established at the time of service origination. Although PVCs are used with Frame Relay, they still maintain an automatic alternate routing capability to ensure reliability (TAYL93 p. B12).

b. Switched Multimegabit Data Service

Switched Multimegabit Data Service (SMDS) is a connectionless datagram service which operates over fiber optic medium at speeds of 1.544M-bps to 45M-bps. SMDS can be

configured to use either data frames or, more commonly, data cells (TAYL93 p. B10).

SMDS is a metropolitan area data transmission service that provides any-to-any connectivity. When configured to use data cells, SMDS is capable of much higher speeds because the delay in transmitting cells is less in duration and is more predictable.

c. Asynchronous Transfer Mode

Asynchronous Transfer Mode (ATM) is a high speed (into the giga bits-per-second range), connection oriented, cell based transmission scheme that can carry both packet-based data traffic and isochronous traffic, such as voice and video on the same network. ATM provides bandwidth on demand for services such as SMDS. ATM cells are 53-bytes longs, five bytes of which are a header that contains virtual circuit and virtual path identifiers (SMAY92 p. 15).

ATM is commonly associated with Broadband Integrated Data Service (BISDN). BISDN actually consists of two "modes": Synchronous Transfer Mode (STM) and ATM. In the BISDN context, "synchronous" refers to a constant stream of data, as associated with time division multiplexing and circuit switching. "Asynchronous" refers to a discontinuous stream of data. The isochronous capability is achieved through data buffering at the destination. Once buffered, the data is

extracted as needed to appear as though it is received in a continuous stream (TAYL93 p. B11).

These three broadband technologies, although separate and having their own strengths and weaknesses, are in fact complementary technologies that provide complementary services. Neither frame-based nor cell-based technologies are inherently better for *all* applications. As is the case in most instances, the exact system performance will be affected most severely by the actual implementation of the technology.

However, for purposes of evaluating which of these broadband technologies will best support multimedia applications, ATM displays the best characteristics to meet the requirements. Its ability to handle various types of traffic (voice, data, and video) at very high speeds with minimal latency fulfills the needs for realtime and interactive computing.

B.   DEDICATED SERVICE

In contrast to switched circuits which enable dynamic connections, dedicated service is primarily associated with permanent connections. Dedicated service is normally identified with privately leased lines from common communication carriers.

A privately leased line is one that permanently connects the terminal equipment so that information can be transmitted at any time without the need to establish a connection as is

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done with switched telephone networks. The lines that are used are the same as those used in the telephone network except that they bypass the switching equipment in the telephone exchanges. Leased lines can be point-to-point or point-to-multipoint. By using suitable line-splitting equipment, one can extend the one line to a number of locations to set up a multipoint line (HOUS87 p. 340).

Leased lines can be either two-wire or four-wire. Normally, a two-wire line is only capable of sending data in one direction at a time. Four-wire lines are used to achieve true full-duplex (simultaneous bi-directional) operations. Four-wire lines are capable of being *conditioned*, which means their signal quality can be enhanced, resulting in greater data carrying capacity (HOUS87 p. 341).

There are two primary types of leased lines associated with high-speed dedicated services.

1. T1

Originally, T1 referred to a system of copper wire cables and repeaters that reinforce a *digital* signal at intervals of about one mile. Currently, T1 implies any digital transmission system that is capable of two-way transmission at 1,544,000 bits per second (1.544M-bps). Such capacity is capable of carrying data from 160 computer ports running at 9600 baud each, or 24 phone conversations in digital form

(each voice channel is operating at 64k-bps). T1 is based upon DS-0 channels of 64k-bps each.

The primary advantage of T1 circuits is that of cost savings. Despite seemingly high start-up costs for equipment and a monthly charge for the leased line, an investment in a network based T1 can break even within the same fiscal year.

Other advantages of T1 circuits include greater network control (diagnostics and configuration), simplification of network management (more connections are routing over one circuit), and improved quality and reliability.

One of the early draw backs of T1 circuits was that they were only available in full T1 configurations of 24 64k-bps channels. Sometimes a company had needs which were only being marginally met by a circuit switched network, yet their requirements couldn't fully justify the cost of a full T1 circuit. As a result of an increasing number of customers being in this situation, *fractional* T1 services were introduced in 1989.

Fractional T1 offers intermediate bit rates that permit a customer to economically justify T1 type service with its inherent advantages of quality, reliability, etc. Typical fractional T1 packages are 1/24, 1/12, 1/6, 1/4, 1/3, and 1/2 of full T1 capabilities.

T1 and fractional T1 circuits possess the individual channel bandwidth required to support multimedia data

exchange. The ability to dedicate one or more channels to a single user also provides the isochronous capability required for low delay times.

2. T3

When the transmission capacity of a T1 circuit is no longer enough, one can obtain the services available in a T3 circuit. T3 refers to a *digital* transmission facility running at 44.735M-bps. A T3 circuit uses microwave systems or optical fiber cable as its transmission media to handle what is equivalent to 28 T1 channels. T3 was originally designed to be used as interexchange trunks within the public telephone network, but it is now also offered as a tariffed service (FLEM89 p. 82). T3 circuits are better suited than T1 circuits to support multimedia types of communication, such as videoconferencing, because of its ability to provide the minimum of 1.5M-bps per channel required for uncompressed full motion video at 30 frames per second.

T3 provides the same advantages as T1 such as: economy, quality, reliability, and enhanced control. As economical as T1 circuits are, T3 circuits improve on cost savings. Although equivalent to 28 T1 channels, T3 is more economical than a much less number of T1s. For example, at a distance of less than 50 miles, only four T1s are required to break even (FLEM89 p. 86).

C. BROADCAST SERVICES

In a broadcast network there are no intermediate switching nodes. At each station, there is a transmitter/receiver that communicates over a medium shared by other stations. A transmission from any one station is broadcast to and received by all other stations. A simple example of this is a citizen band (CB) radio system, in which all users tuned to the same channel can communicate. Since the medium is shared, only one station at a time can transmit (STAL91 p. 8).

There are three primary types of broadcast networks: packet radio networks, satellite networks, and local networks.

1. Packet Radio Networks

In a packet radio network, stations are within transmission range of each other, and broadcast directly to each other using the same data packets as described in section A.3. Packet radio systems were developed to bypass the local telephone networks which were generally not capable of providing high-speed data lines. Although this is usually not the case today, packet radio still provides the advantage of operating one's own network while avoiding the high costs of paying a common carrier (HOUS87 p. 164).

The architecture of packet radio networks can be classified as centralized or decentralized. In a centralized network, there is one transmitter/receiver attached to a central resource. All other nodes communicate only with the

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central node. Node-to-node communication is indirect, mediated by the central node. This centralized configuration is rather impractical for today's information exchange requirement for speed.

The distributed architecture takes full advantage of the omnidirectional property of radio. One channel is used for all transmissions and each transmission is heard by all other nodes. This configuration is logically equivalent to a local area network.

In most cases packet radio systems are designed with nodes within radio line of sight propagation. If nodes are not within radio line of sight they can still be connected to the network via a repeater. A repeater operates in a store-and-forward mode and performs much the same task as a node in a packet switched network (STAL91 p. 334).

Because of the shared media characteristic of packet radio, it uses Collision Sense Multiple Access (CSMA) as its method of controlling access to the channel. Therefore, the opportunity for data collision exists, resulting in no guarantee that any one station can efficiently get its data through to its destination.

As a result, just as is the case with wireless LANs, when media access control is an issue, variable delays in data transmission can be expected. For this reason, packet radio networks have a limited capability to handle multimedia information.

2. Satellite Networks

The advantage of satellite communication is that the satellite can provide very wide area coverage on the ground, and within view of the satellite, one is able to set up an earth station and immediately get very high quality communications with other earth stations. This capability is of great value to developing countries and in areas where long terrestrial distances are involved (HOUS87 p. 328).

The vast majority of communication satellites are in geosynchronous orbit, meaning they are stationary above a region of the earth's surface, and at an altitude of 35,700 km can provide an area coverage of approximately one-third of the surface of the earth. The down-link radio wave from the satellite to an earth station can be focused much like the light beam of a flashlight. Similar shaping of the up-link signal is possible. This capability provides a means to cover a larger or smaller area, while a more focused beam provides greater signal quality.

Satellite links can be configured for point-to-point or point-to-multipoint transmissions, and are typically used to carry bulk, long haul transmission traffic in much the same way as coaxial cable, terrestrial microwave or fiber optic cable.

Satellites operate in the 4/6G-Hz bands and typically provide a 500M-Hz bandwidth that is broken up into 12 40M-Hz

channels. Each channel is capable of carrying one of the following:

- 1200 voice channels.

- One 50M-bps data stream.

- 16 channels of 1.544M-bps each.

- 400 channels of 64k-bps each.

- 600 channels of 40k-bps each.

Satellite networks have the ability to separate their bandwidth into separate channels which can be dedicated to a specific, single user. When allocation is done in this manner, although it may not be the most efficient use of the available bandwidth, it certainly provides the ability to handle wide bandwidth, continuous stream data such as multimedia.

3. Local Networks

Broadcast networks in a local area environment are covered extensively in Chapter III.

VI. CONCLUSION

A. SUMMARY

Multimedia holds the promise of increased knowledge, creativity and productivity for virtually any application that can be imagined. The ability to present information in both an informative and entertaining way can lead to an enhanced quality of life for an increasingly larger segment of the world's population.

Information generated in a multimedia format presents special challenges for communications networks. The large file sizes associated with multimedia information, consisting of voice, video, graphics and text, dictate that networks provide high-bandwidth channels.

An equally critical characteristic of multimedia information which must be considered in developing or choosing the correct communication network is the requirement for low delay times, or latency. Multimedia information is especially sensitive because of the requirement to synchronize voice and video information into an audiovisual format.

Data communication capabilities over the past decade have developed to meet the ever increasing demand for high volume data transfer. However, the majority of data have been in a single medium, such as voice or text. Because of this,

separate information circuits have evolved which are efficient in handling one or the other type of traffic, but not both. The advent of multimedia is causing the distinction between voice and data networks to become blurred, and in the near future will drive such a distinction into the communication history books.

The challenge today is the continued development and deployment of communications technologies and architectures. Such advances must be sophisticated enough to handle multimedia data, yet affordable enough to permit their widespread use. Both hardware and software capabilities are improving that will permit the near future availability of new services, such as envisioned by Personal Communication Networks.

B. RECOMMENDATIONS

A number of the current transmission media and architectures are capable of supporting multimedia. The question is how does one maximize his utilization of current assets to meet his current and future needs?

In the optimal scenario, current hardware could be discarded in favor of the newest network hardware and services. Top of the line personal computers or workstations would be sending multimedia data over fiber optic cable from the desktop to wide area networks consisting of ATM switches running at gigabytes speed over fiber optic trunks.

The reality of the situation, however, is that current networks must be used to their maximum potential until phased change-outs can be justified and implemented. High bandwidth and isochronous requirements for the delivery of multimedia information must be met now, with today's available technology. It can be done! But, at what expense?

Limiting the size of networks or re-engineering current networks through creative reconfiguration will permit the transfer of multimedia information by reducing the number of individual nodes that can claim network access. Yet, doing so deletes one of the reasons for establishing the network in the first place: increased connectivity to others.

Therefore, an appropriate communication media must be one that is not only robust enough to provide the required bandwidth for efficient throughput, it must also do so in an expeditious manner to permit the information recipient to realize the full effect of multimedia presentations.

Organizations with established networks will face the greatest challenge in optimizing them to handle multimedia traffic. Network managers responsible for developing new networks will be well served to look well beyond today's requirements for bandwidth and low delay. Short term goals must be the foundation for long term success.

Equally important as network speed is its ability to be *interoperable* with networks of lesser capabilities and different traffic handling protocols. One must always remember

that cooperative computing power is derived from the variety of information resources which can be tapped.

There is no single best solution today for extracting the full potential of multimedia computing without unlimited funds and influence. Rather, success is possible through continued development of emerging technologies, while getting the most from today's capabilities via detailed analysis and network configuration.

Two areas of further research are warranted. Continued research and development of economical production techniques of optical fiber cable and connecting devices should be pursued. The bandwidth capacity and physical characteristics of optical fiber make it the primary choice for *guided* media in the future.

U.S. Federal government agencies and standards organizations need to increase their interaction with other national governments and standards organizations in developing standards for personal communication networks (PCN). Research should be conducted which focuses on the impact to the U.S. if we don't become proactive in this issue.

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